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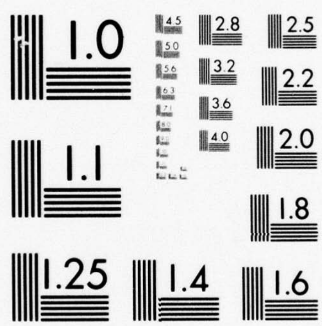
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RM-628

DETECTION ASPECTS OF AN OPTICAL MATCHED FILTER IMAGE CORRELATOR

March 1977

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Grumman Aerospace Corporation	2a. REPORT SECURITY CLASSIFICATION Unclassified
	2b. GROUP N/A

3. REPORT TITLE

(6) Detection Aspects of an Optical Matched Filter Image Correlator.

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

(9) Research Memorandum

5. AUTHOR(S) (First name, middle initial, last name)

(10) Glenn M. Mehalek (12) 41p.

6. REPORT DATE (11) March 1977	7a. TOTAL NO. OF PAGES 33	7b. NO. OF REFS 8

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S) (14) RM-628
b. PROJECT NO.	
c. N/A	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) None
d.	

10. DISTRIBUTION STATEMENT

Approved for Public release; distribution unlimited.

11. SUPPLEMENTARY NOTES None	12. SPONSORING MILITARY ACTIVITY None

13. ABSTRACT

Aerial photography for reconnaissance purposes is currently examined by human photointerpreters — a slow, costly, tedious process. Grumman, however, has developed an Optical Matched Filtered Image Correlation technique for automating the screening of aerial reconnaissance film. For the investigation described in this document, some detection aspects of this system were examined.

A set of matched filters was made for an M-60 Army tank. A set of three filters varying in optimized spatial frequency was then selected. Correlation signal-to-noise ratios were obtained, and normalizations of the correlation plane signals to total scene intensity and total correlation plane intensity were performed. A simple thresholding technique was suggested. A point-by-point normalization technique was proposed with the intent of improving the signal-to-noise ratio for the system, and a simple application of this technique was implemented.

DD FORM 1 NOV 65 1473

406 165

Unclassified

Security Classification

7/B

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT

Security Classification

(12)

Grumman Research Department Memorandum RM-628

DETECTION ASPECTS OF AN OPTICAL MATCHED FILTER IMAGE CORRELATOR†

by

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System Sciences

March 1977

† Also submitted to the Graduate Faculty of Rensselaer Polytechnic Institute in Partial Fulfillment of the Requirements for the Degree of Master of Engineering.

Approved by: Richard A. Scheuing
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406 165

ACKNOWLEDGMENTS

The author wishes to express his gratitude to Mr. Ron Wohlers and Mr. Ken Leib for their assistance and guidance in the work carried out in the Grumman Research laboratories. Thanks are also extended to project advisor Dr. Pankaj Das for his supervision and assistance.

ABSTRACT

Aerial photography for reconnaissance purposes is currently examined by human photointerpreters — a slow, costly, tedious process. Grumman, however, has developed an Optical Matched Filtered Image Correlation[†] technique for automating the screening of aerial reconnaissance film. For the investigation described in this document, some detection aspects of this system were examined.

A set of matched filters was made for an M-60 Army tank. A set of three filters varying in optimized spatial frequency was then selected. Correlation signal-to-noise ratios were obtained, and normalizations of the correlation plane signals to total scene intensity and total correlation plane intensity were performed. A simple thresholding technique was suggested. A point-by-point normalization technique was proposed with the intent of improving the signal-to-noise ratio for the system, and a simple application of this technique was implemented.

[†] U.S. patent 3,779,492

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1. INTRODUCTION

In 1964, A. B. Vander Lugt demonstrated a method for synthesizing frequency plane filters for coherent optical processing systems (Ref. 1). By generating the filters interferometrically, he was able to control both the amplitude and phase of a transfer function using only a real-valued function on a spatial carrier frequency. This development opened many doors in the field of coherent optical processing systems.

Coherent optical processing systems are based upon the ability of a simple converging lens to perform a two dimensional Fourier transformation (Ref. 2). Such a system is shown in Fig. 1. A collimated beam illuminates the input plane, which has an amplitude transmittance of the desired matched filter impulse response, m. Lens L_1 performs the Fourier transformation on the amplitude distribution m so that the amplitude distribution incident on the film is

$$\frac{1}{\lambda F}\mathcal{F}[m(x,y)] = \frac{1}{\lambda F} M\left(\frac{x'}{\lambda F}, \frac{y'}{\lambda F}\right)$$

where $\mathcal{F}$ denotes the Fourier transformation. The upper collimated beam, called the reference beam, produces a field distribution

$$R_o \exp(-j2\pi\mu y')$$

Where μ is the spatial carrier frequency $\sin\theta/\lambda$, let

$$M\left(\frac{x'}{\lambda F}, \frac{y'}{\lambda F}\right) = \left|M\left(\frac{x'}{\lambda F}, \frac{y'}{\lambda F}\right)\right| \exp\left[-j\psi\left(\frac{x'}{\lambda F}, \frac{y'}{\lambda F}\right)\right].$$

The intensity distribution on the film can then be written

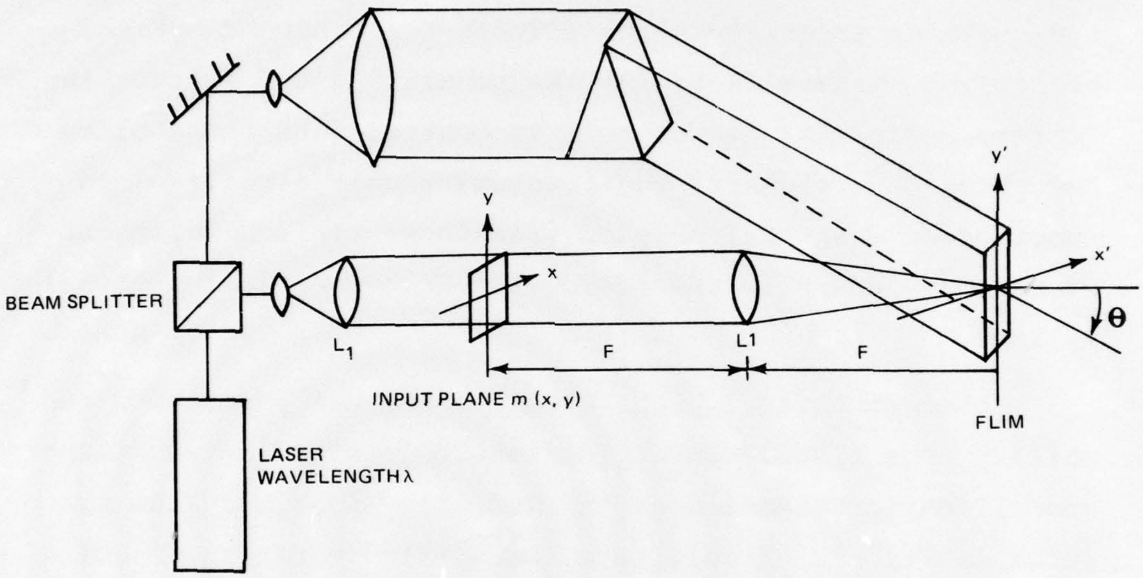

Fig. 1 Vander Lugt Matched Filter Fabrication

$$I(x',y') = R_o^2 + \frac{1}{\lambda^2 F^2}\left|M\left(\frac{x'}{\lambda F}, \frac{y'}{\lambda F}\right)\right|^2 + \frac{R_o}{\lambda F} M\left(\frac{x'}{\lambda F}, \frac{y'}{\lambda F}\right)\exp(j2\pi\mu y')$$

$$+ \frac{R_o}{\lambda F} M^*\left(\frac{x'}{\lambda F}. \frac{y'}{\lambda F}\right)\exp(-j2\pi\mu y')$$

$$= R_o^2 + \frac{1}{\lambda^2 F^2}\left|M\left(\frac{x'}{\lambda F}, \frac{y'}{\lambda F}\right)\right|^2$$

$$+ \frac{2R_o}{\lambda F}\left|M\left(\frac{x'}{\lambda F}, \frac{y'}{\lambda F}\right)\right| \cos\left[2\pi\mu y' - \psi\left(\frac{x'}{\lambda F}, \frac{y'}{\lambda F}\right)\right]$$

If the film is developed and has a linear amplitude transmittance curve, the amplitude transmittance of the film is proportional to

$$R_o^2 + \frac{1}{\lambda^2 F^2} |M|^2 + \frac{R_o}{\lambda F} M \exp(j2\pi\mu y') + \frac{R_o}{\lambda F} M^* \exp(-j2\pi\mu y')$$

If this transparency is inserted in the frequency plane of the optical processing system of Fig. 2, where $p(x,y)$ is the function to be filtered, three distributions of light will appear at the output. The first term, which appears on the optical axis, is not generally of interest (Ref. 3). Deflected to each other side of the central term are two additional images (Ref. 4). One of these, centered at $(0,\mu\lambda F)$ in the output plane, is proportional to the convolution of m and p

$$\iint_{-\infty}^{\infty} m(-x'' - \xi, -y'' + \mu\lambda F - \eta)\, p(\xi,\eta)\, d\xi d\eta$$

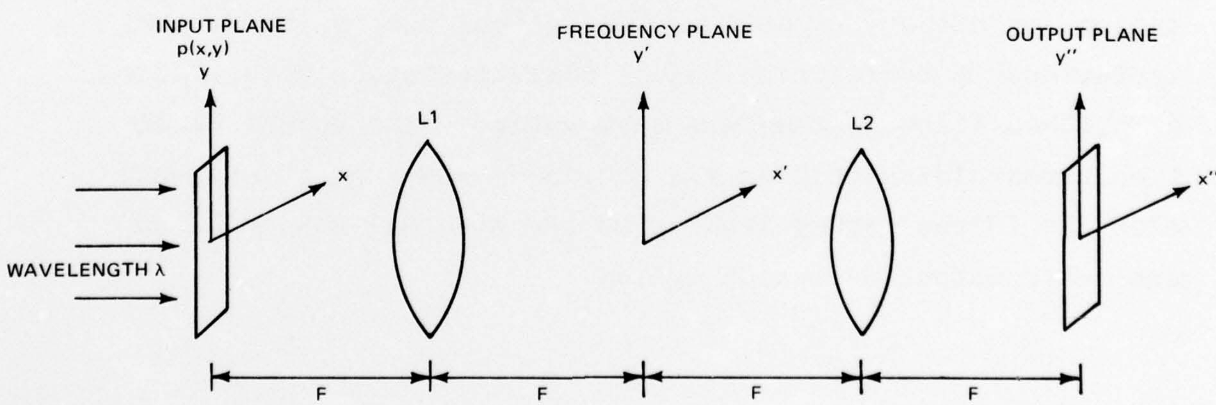

Fig. 2 Basic Coherent Optical Processing System

The other image, centered at $(0, -\mu\lambda F)$ in the output plane, is proportional to the cross correlation of m and p

$$\iint_{-\infty}^{\infty} p(\xi,\eta)\, m^{*}(\xi + x'', \eta + y'' + \alpha\lambda F)\, d\xi d\eta$$

It is this cross correlation signal that was used in the reconnaissance film processing system.

This project evolved from an investigation performed at Grumman for the U.S. Army Night Vision Laboratory (Ref. 5). The program included a determination of matched filter sensitivities to independent variations in image parameters of an M-60 tank. Variations in target size, contrast, resolution, and target orientation were investigated. The program objective was to develop an automatic screening system for aerial reconnaissance film that would decrease dependence upon human photointerpreters.

The project described here was concerned with the correlation, or output, aspects of the optical processing system. Variations in correlation signal characteristics were studied as matched filter parameters were varied. The output detection thresholding problem was examined, and suggestions were made for further study leading to the eventual design of an automatic output detection system.

2. METHOD OF PROCEDURE

The optical processing system used in this investigation was set up on a three meter long, 7000-pound flat granite table isolated from ground vibration by spring supports. A 15 mW spectra-physics 124A He-Ne laser powered the system (Fig. 3), and an electronic shutter timed exposures for matched filter (MF) fabrication. The beam from the laser entered a beam splitter, and then each of the resultant beams were filtered and expanded by lens-pinhole collimating lens assemblies. A liquid gate mounted in the reference beam was used for attenuating the beam, using gelatin neutral density filters. The collimated reference beam was then directed to the frequency, or MF, plane.

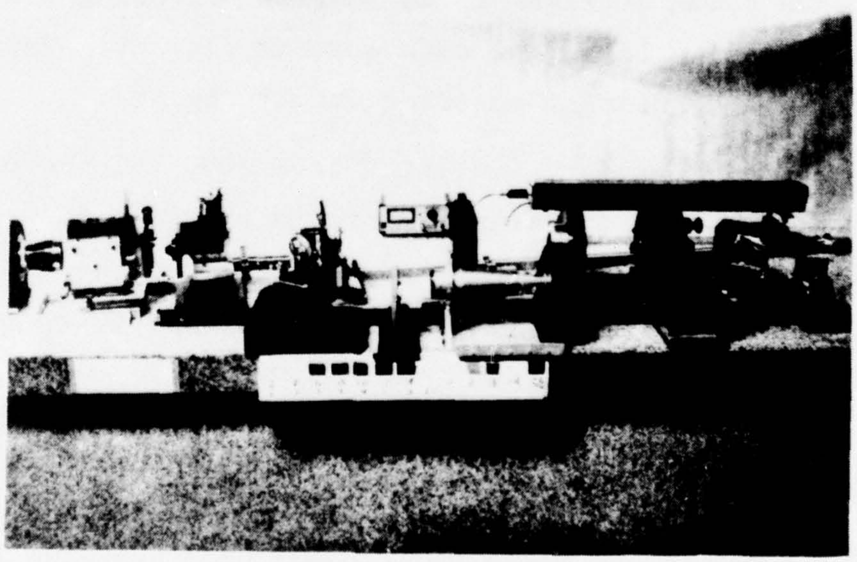

Fig. 3 Experimental Target Recognition System

The signal beam, after collimation, was incident on the transparency contained in a rotating liquid gate. The liquid (decahydronapthalene) provided an index matching mechanism that reduced phase distortion in the beam. The rotational nature of the gate facilitated the measurement of system sensitivity to target orientation in the investigation (Ref. 5).

The signal beam amplitude modulated by the transparency was incident upon a Grumman-made (Ref. 5), bromine-bleached (Ref. 6) 360 mm holographic lens located 360 mm away from the transparency plane. The holographic lens displayed the Fourier transform of the modulated beam in the MF plane, located at the back focal point of the lens. The angle between the reference beam and the signal beam was set at 10°. Care was taken to ensure that the optical path lengths of the two beams were equal. All optical elements were carefully positioned along straight rails and aligned using the back reflections of a beam from each optical element. The beams were collimated using a shearing interferometer.

A modified Gamma-Scientific Model 2000 Telephotometer was used for intensity measurements in the MF plane. The calibrated instrument was fitted with a microscope objective and scanning probe, facilitating the measurement of the intensity distribution of the tank spectra. By using different probe sizes, peak detection with varying degrees of intensity averaging was accomplished.

After determining the desired exposure and beam ratio for the fabrication of a matched filter, an Eastman-Kodak 120-02 photographic plate was exposed to both beams simultaneously in the frequency plane. The plate was developed in the following sequence:

1. Develop 5 minutes in Kodak D-19; agitate for 5 seconds every 30 seconds
2. Wash in deionized water for 30 seconds
3. Stop 30 seconds in Kodak Stop Bath
4. Wash in deionized water for 30 seconds
5. Fix in Kodak Rapid Fixer with hardener for 4 minutes; agitate for 5 seconds every 30 seconds
6. Wash in deionized water for 1 minute
7. Hypo clear in Kodak Hypo Clear for 3 minutes; agitate 5 seconds out of every 30 seconds
8. Wash in deionized water for 5 minutes
9. Photo-flo in Kodak Photo-Flow solution for 30 seconds
10. Dry at room temperature

The developed plate was then replaced in its initial position in the frequency plane. When illuminated by the signal beam, a portion of the beam was diffracted in the direction of the original reference beam. This signal was incident on a 100 mm retransform lens, which displayed the correlation signal in its back focal plane. The Gamma-Scientific photometer was positioned through the use of an X-Y translating mount, and the instrument's different size probes were used for different modes of measurement.

3. RESULTS

MATCHED FILTER FABRICATION AND SELECTION

The matched filters used in this investigation were made using the "standard" M-60 as the object. Each consisted of a 35 mm frame with a 1 x 2 mm M-60 tank on an opaque background (Fig. 4). The contrast of the tank was high and the detail sharp (this is not apparent from Fig. 4). Since the background was opaque, no aperture effects were observed (Ref. 7). The standard M-60 was very close in size and detail with the tanks in the simulated reconnaissance films, which are described below.

Many matched filters were made before the set used in this work was obtained, as several problems were encountered.

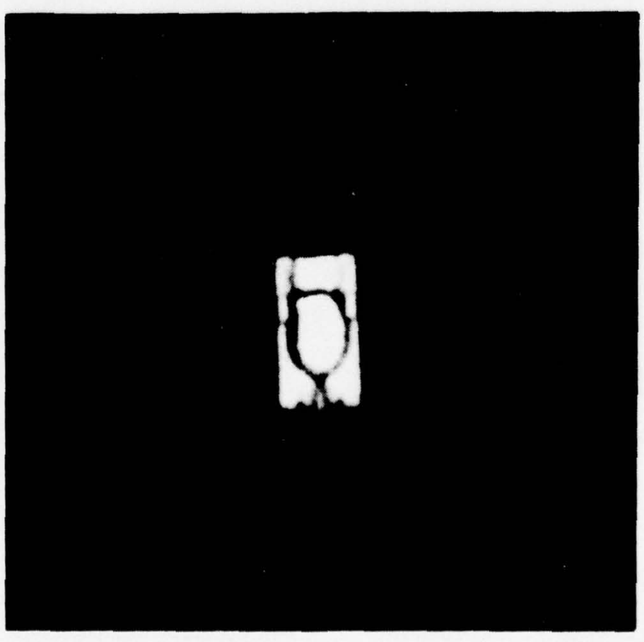

Fig. 4 Standard M-60 Tank

Filters were made from different standard tanks varying in size, detail, and contrast before a standard was found that correlated well with the balance of the reconnaissance film. After the standard M-60 was chosen, matched filters were made and correlation measurements taken to gain familiarity with the characteristics of the fabrication and measurement process.

When a repeatability test was performed for the measurement of the peak autocorrelation signal for a given matched filter, unsatisfactory results were obtained, as the peak intensity of the autocorrelation signal was dropping significantly each day. After testing several components of the optical system, it was determined that the efficiency of the holographic lens was diminishing rapidly. Further tests indicated that the ambient humidity was damaging the bromine-bleached emulsion on the holographic lens.[†]

A new holographic lens was installed in the system, and steps were taken to reduce the humidity in the area of the lens. The efficiency of the new lens was monitored for the balance of the investigation, and the results were satisfactory.

Matched filters were subsequently made from the standard tank. A convention was adopted for ordering the lobes in the spatial frequency spectrum of the tank (Fig. 5). Along the axis of the spectrum perpendicular to the longitudinal axis of the tank, lobes were counted from the center of the spectrum (DC or 0 order) out of the sides. Thus the third lobe from the center on the horizontal axis was labeled 3rd order.

[†] This problem is currently under investigation and is near solution.

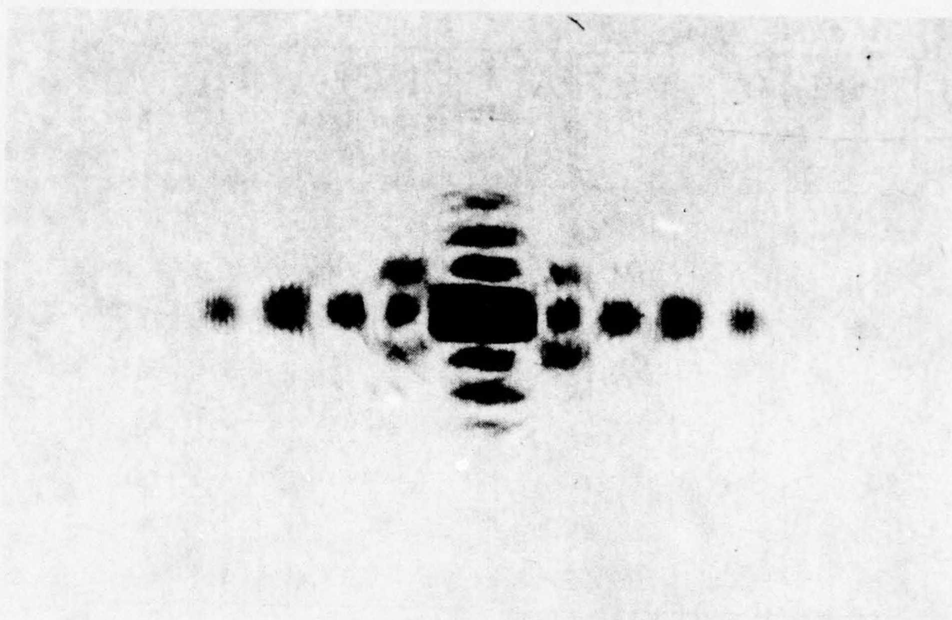

Fig. 5 Spectrum of M-60 Tank

Table 1 shows the displacements of the centers of these lobes from the center of the frequency plane. Also summarized are the corresponding spatial frequencies ($X/\lambda F$) associated with these displacements. The relative peak intensity of each lobe, as measured with a probe covering a small area (700 square microns) in the center of each lobe, is also shown.

Based upon past experience, matched filters were constructed that were optimized for the DC, 3^{rd}, and 6^{th} lobes. The 3^{rd} order filter has been previously shown to be effective (in terms of sensitivity and discrimination) for this application (Ref. 5). To optimize a particular lobe, the intensity of the signal and reference beams were made equal for that lobe. Maximized carrier modulation at the optimized

TABLE 1 SPECTRUM OF THE STANDARD M-60 TANK

Lobe	Position x', mm	Spatial Frequency cycles/mm	Relative Intensity
Center DC	0	0	0
Edge DC	0.215	0.940	0.153
1	0.312	1.36	0.0093
2	0.516	2.27	0.0104
3	0.742	3.26	0.0113
4	0.978	4.19	0.0037
5	1.194	5.24	0.00097
6	1.409	6.19	0.0014

spatial frequency was the result. The selected frequency determines the sensitivity of the correlation signal to scale size, target orientation, and detail variations of the imagery being processed.

A series of exposure variations was performed for each order matched filter. Autocorrelation measurements were then performed for each series. Figure 6 shows the relative peak autocorrelation intensity versus the reference beam exposure level. The peak autocorrelation signal occurred in each case when the reference beam energy density exposure was 200 ergs/ cm^2, as measured with a Tektronics J-16 Digital Photometer. One matched filter from each set was selected for further study on the basis of this maximum peak autocorrelation output, as measured with a probe covering approximately 80 sq microns in the correlation plane. Figures 7, 8, and 9 are microphotographs of the selected DC, 3^{rd}, and 6^{th} order

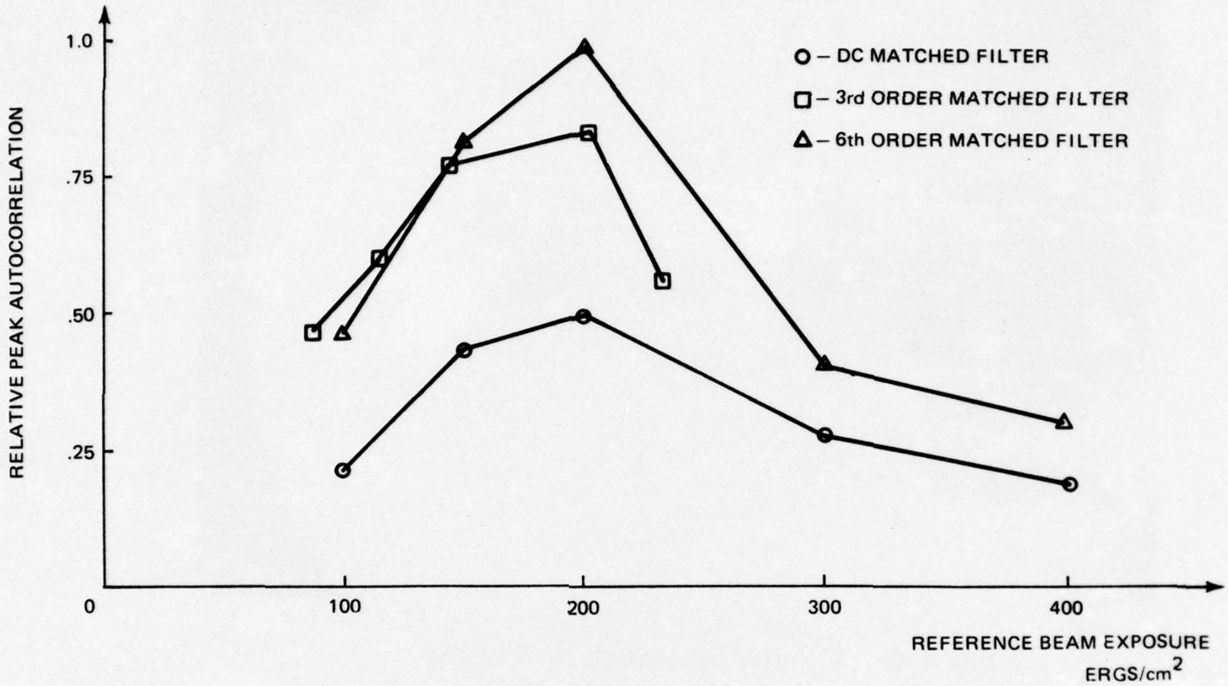

Fig. 6 Relative Autocorrelation Versus Reference Beam Exposure Level

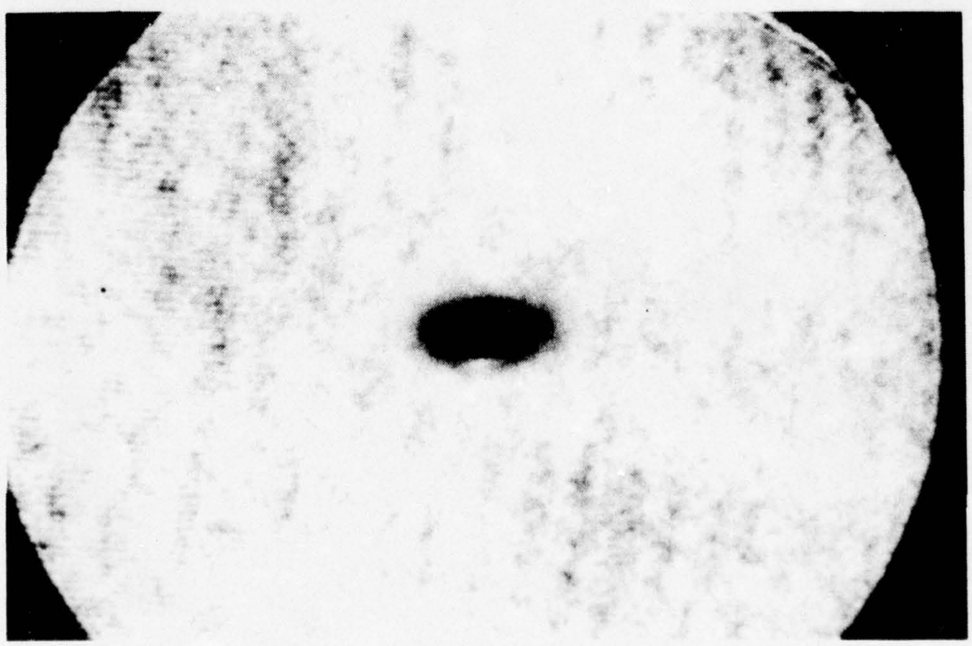

Fig. 7 DC Matched Filter

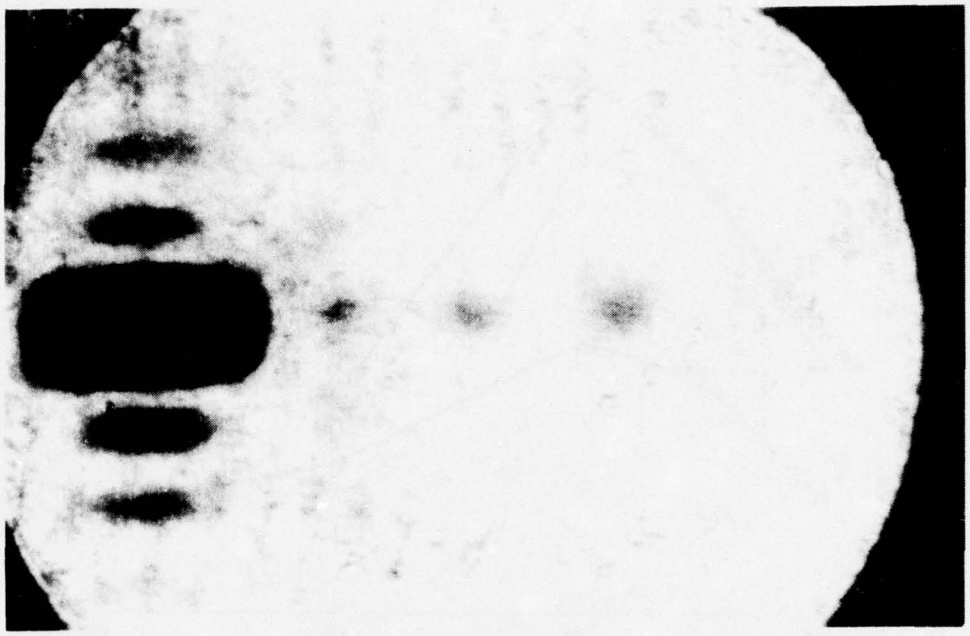

Fig. 8 3rd Order Matched Filter

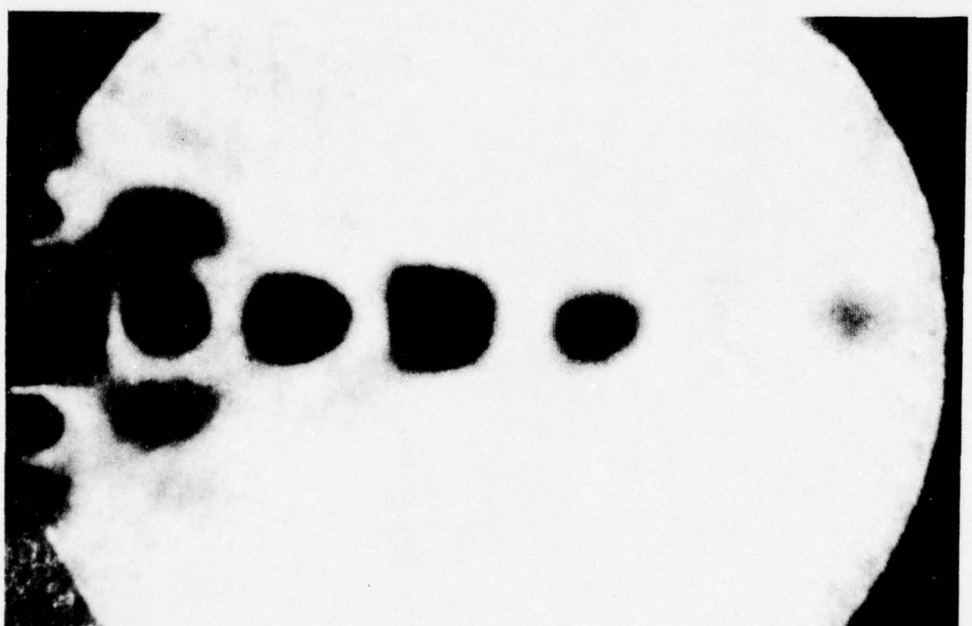

Fig. 9 6th Order Matched Filter

filters, respectively. Figure 10 is an enlargement of Fig. 7 showing the carrier "fringes" on the matched filter. Figures 11, 12, and 13 show the autocorrelation signals for the three respective filters. As the order of the filter increased, the detail in the autocorrelation signal became finer.

The sizes of the (centrally located) peaks of the autocorrelation signals were measured. For the DC signal, the peak measured approximately 0.33 x 0.66 mm; for the 3rd order case it measured 0.07 x 0.22 mm; and for the 6th order case, 0.06 x 0.19 mm.

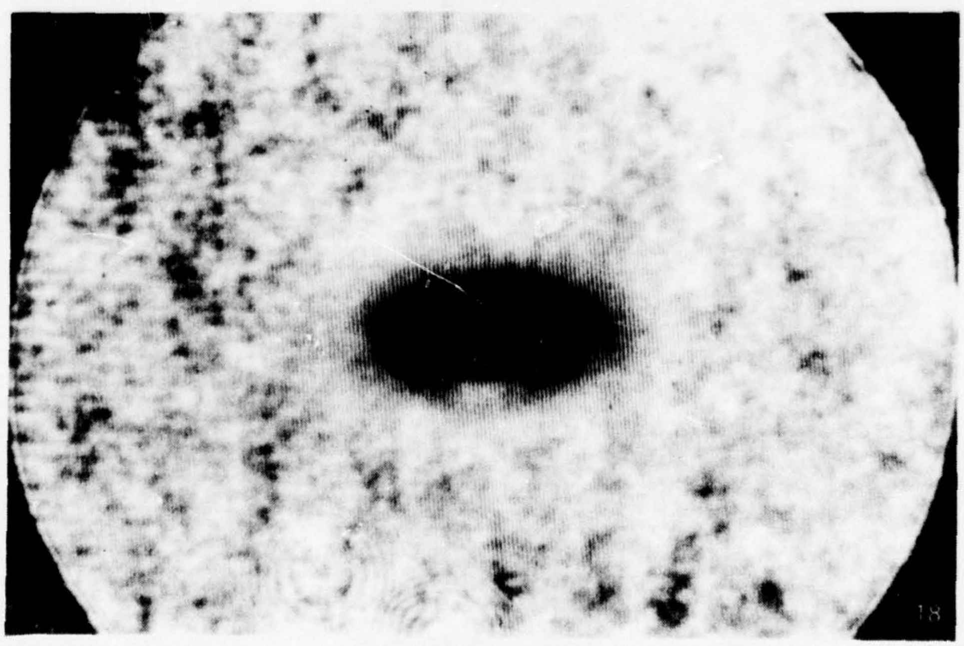

Fig. 10 Enlargement of DC Matched Filter Showing Carrier Fringes

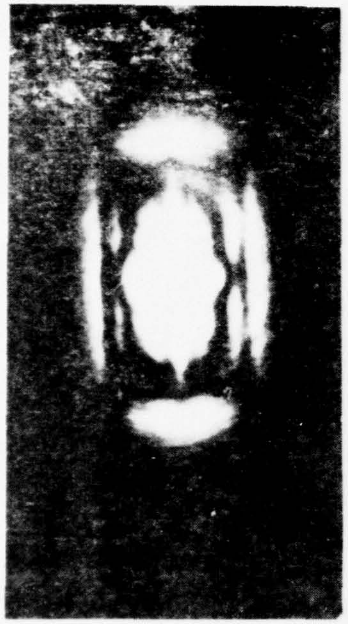

Fig. 11 M-60 Autocorrelation with DC Matched Filter

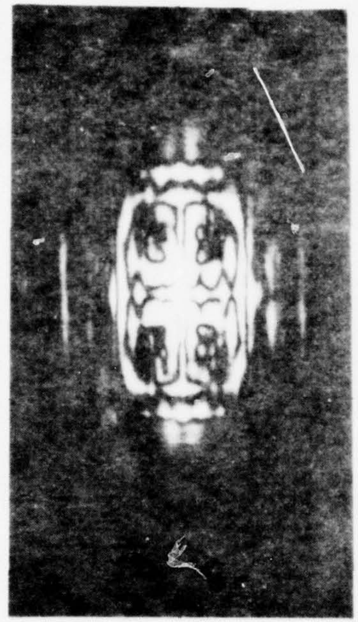

Fig. 12 M-60 Autocorrelation with 3rd Order Matched Filter

Fig. 13 M-60 Autocorrelation with 6th Order Matched Filter

MATCHED FILTER PERFORMANCE

Five different reconnaissance scenes were used. The first three images comprised a series, Recon A, B, and C (Figs. 14, 15, and 16). Each one consisted of a convoy comprising an M-60 tank, two other tanks, and two trucks. The backgrounds varied, but were basically lightly wooded terrain. All the vehicles were dark, with light detail. Overall sharpness was good, but not as good as that of the standard M-60. Recon A and B had relatively dark backgrounds, while the background of Recon C was lighter than that of its M-60.

The next image used was called Recon 84 (Fig. 17). A single M-60 tank was situated in a half-wooded, half-desert scene. The tank was situated at the border of the wooded and sandy areas. The density of the tank was between that of the woods and the sand. The detail of this tank was poor compared to that of the previously described imagery. Only major details of the tank could be seen.

The last image, Recon 121 (Fig. 18), was a simulated farm scene with an M-60 situated at the center. The tank was very dark, with low contrast and poor detail. There were several white buildings, some of which were close to the size of the M-60. This scene was expected to be a "worst case" test of the optical image processing system.

All of the scenes were apertured with a round 18 mm aperture to eliminate effects from the edges of the film and sprocket holes. The sharp edge of the aperture had an effect in the correlation planes (Figs. 19, 20, and 21). All

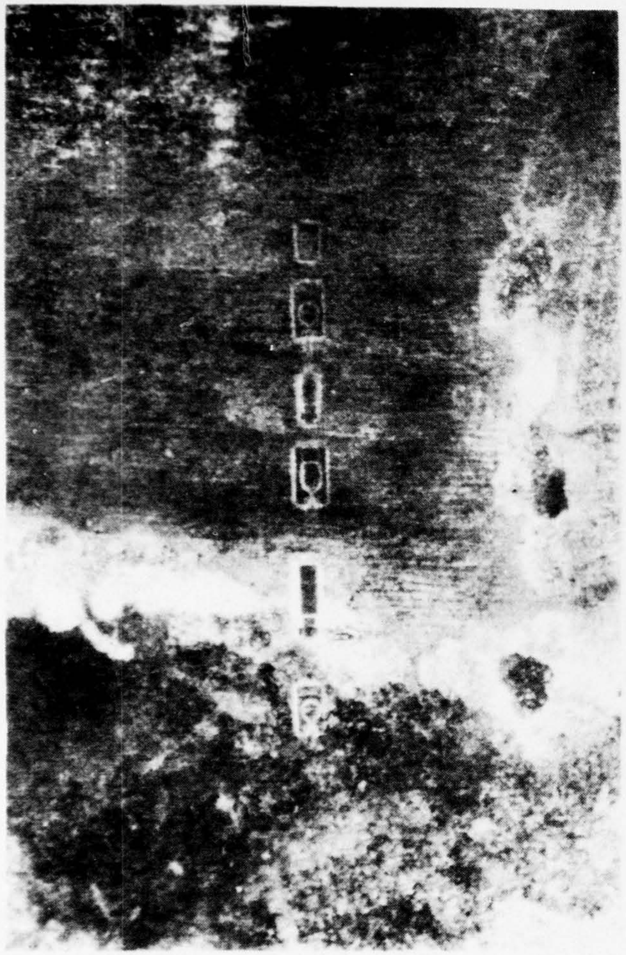

Fig. 14 Reconnaissance Scene A

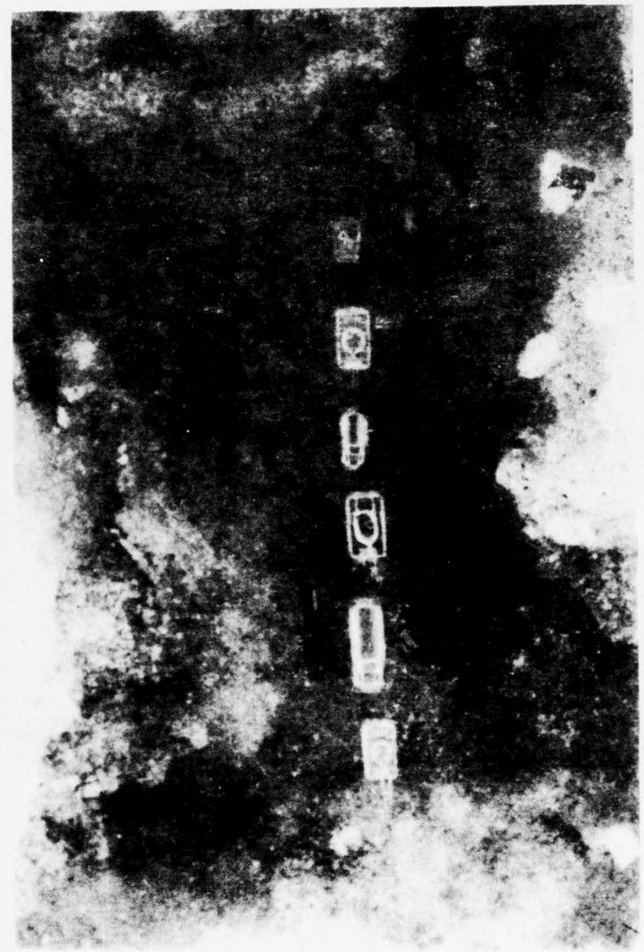

Fig. 15 Reconnaissance Scene B

Fig 16 Reconnaissance Scene C

Fig. 17 Reconnaissance Scene 84

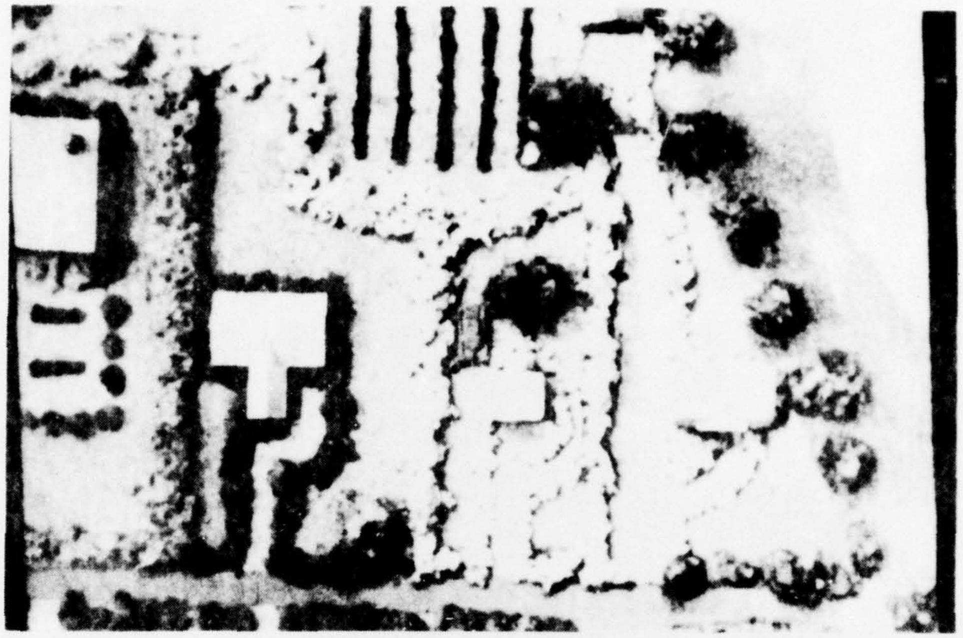

Fig. 18 Reconnaissance Scene 121

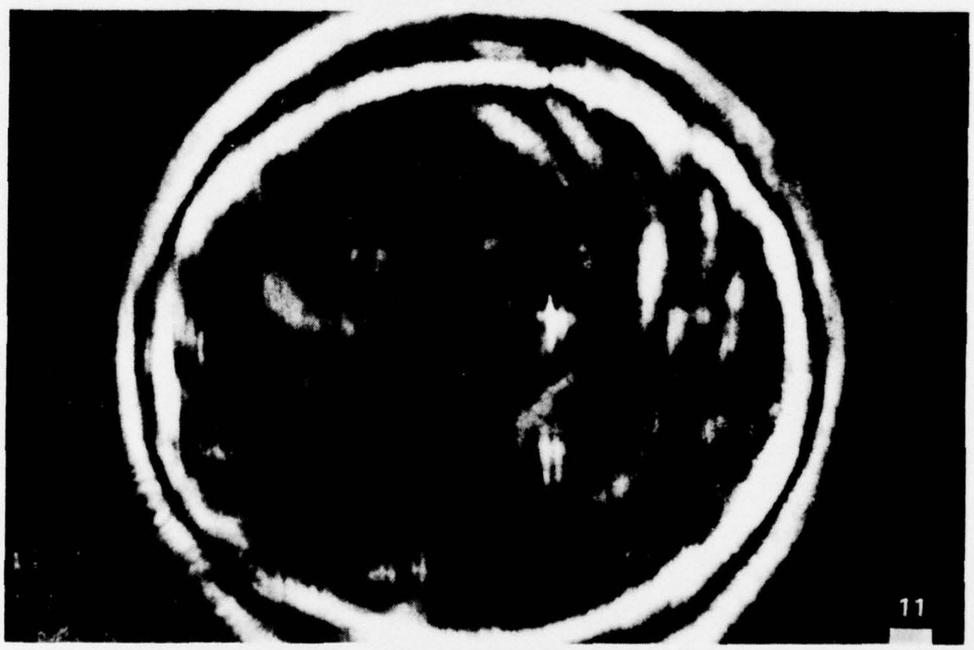

Fig. 19 Correlation Plane for Recon C:
DC Matched Filter

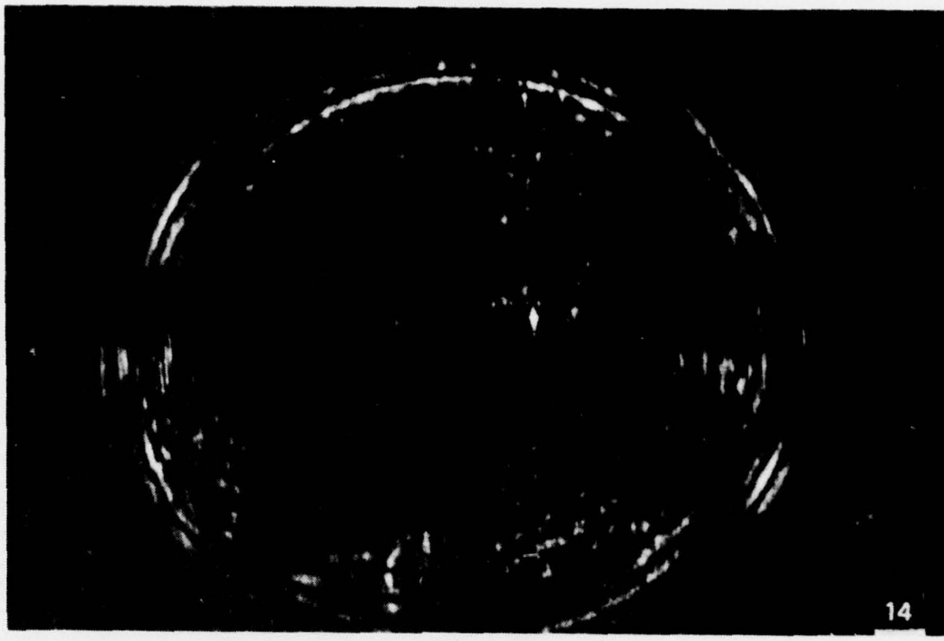

Fig. 20 Correlation Plane for Recon C; 3rd Order Matched Filter

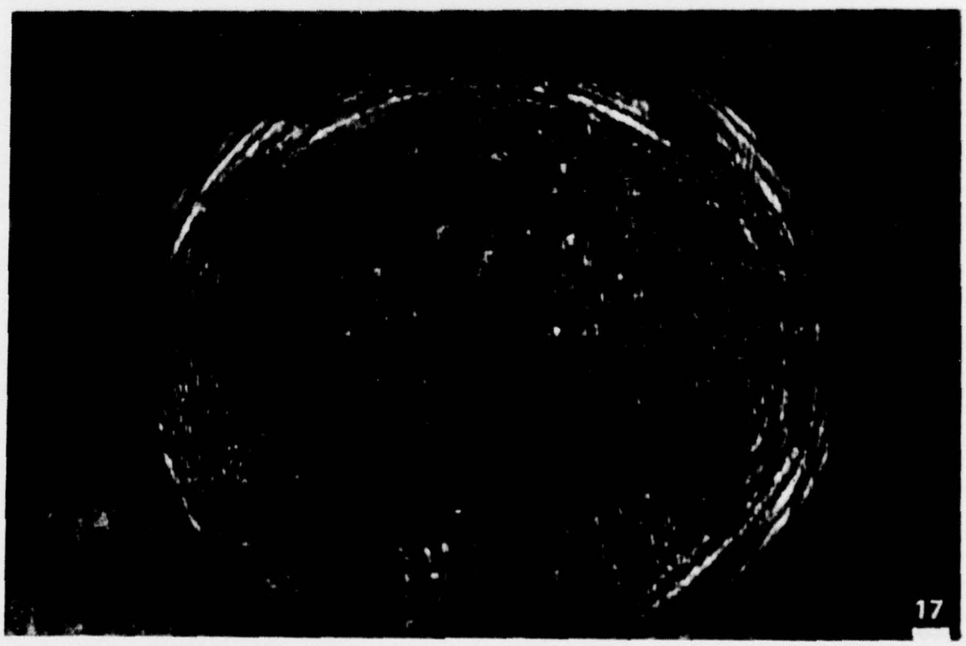

Fig. 21 Correlation Plane for Recon C; 6th Order Matched Filter

measurements of scene energy, signal-to-noise ratio, etc., were made inside these aperture effect rings.[†]

Each recon scene was "played through" the selected DC, 3rd, and 6th order filters. First the standard M-60 was inserted in the rotating gate, and the matched filter micropositioned for maximum autocorrelation output. The recon scenes were then inserted in the gate and rotated so that the tank orientation corresponded with the way the matched filters were made. Figures 19, 20, and 21 show the correlation planes for recon C, when the DC, 3rd, and 6th order matched filters were used.

The correlation and maximum clutter signals were measured within the bounds of the aperture effect. Clutter was defined as any signal in the correlation plane that was not produced by the M-60 tank. Signals produced by other vehicles were included as clutter signals.

Table 2 shows the correlation and peak clutter relative intensities for three different matched filters. Both signals and clutter were measured with a probe having an area of 80 square microns, referenced to the correlation plane and therefore acting as a peak detector.

The 3rd and 6th order matched filters discriminated the M-60 tank for four out of the five recon scenes. The DC filter yielded signal-to-clutter ratios of greater than one in only two cases. The DC filter, less sensitive to detail variations, was more easily "overloaded" by objects other

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[†] An investigation pertaining to the reduction of these aperture effects is in progress.

TABLE 2 CORRELATION MEASUREMENTS FOR RECONNAISSANCE FILM

	Matched Filter								
	DC			3rd Order			6th Order		
Scene	Peak Correl	Peak Clutter	Sig/ Clutter	Peak Correl	Peak Clutter	Sig/ Clutter	Peak Correl	Peak Clutter	Sig/ Clutter
Recon A	0.06	0.03	2.0	0.36	0.04	9.0	0.39	0.03	13.0
Recon B	*	0.05	-	0.175	0.02	8.75	0.175	0.02	8.75
Recon C	0.23	0.06	3.8	0.54	0.05	10.8	0.36	0.05	7.20
Recon 84	0.12	0.35	0.34	0.42	0.07	6.0	0.32	0.1	3.2
Recon 121	0.07	0.16	0.44	0.12	0.24	0.50	0.12	0.25	0.28

*Too low to be measured.

than the M-60, especially when they had a greater intensity transmittance than the M-60.

The matched filters were able to discriminate the M-60 in the farm scene, Recon 121. However, several peaks, particularly those arising from the white buildings, were higher than the autocorrelation peak. This result suggested that the correlation plane might be normalized by the input scene energy, point-by-point. This is discussed in the following paragraphs.

The average intensity of each scene was measured by placing a probe (which covered the total energy transmitted through the scene) near the focal point of the holographic lens. Table 3 shows the average scene intensities relative to the average intensity of the beam that was transmitted when there was no scene inserted in the gate. The total correlation plane energy was then measured for each of the five scenes for the three matched filters. The measurements were made with a probe that covered the entire correlation plane, up to but not including the obvious aperture effect rings. Table 3 shows the average correlation plane intensities relative to the no-scene case for each matched filter.

It was desired to set a threshold above which any signal would be considered an M-60 tank. Only the 3^{rd} and 6^{th} order cases were considered, as these filters picked out the M-60 well. Table 2 shows that the lowest peak correlation exclusive of Recon 121 was 0.175 for both the 3^{rd} and 6^{th} order cases. The highest clutter signal signals were 0.24 and 0.25, respectively, for Recon 121. No simple threshold could therefore be set that would be below the autocorrelation

TABLE 3 AVERAGE SCENE AND CORRELATION PLANE INTENSITY

Scene	Relative Average Scene Intensity	Relative Average Correlation Plane Intensity		
		DC MF	3^{rd} Order MF	6^{th} Order MF
Recon A	0.155	0.238	0.207	0.210
Recon B	0.100	0.129	0.133	0.134
Recon C	0.241	0.301	0.277	0.283
Recon 84	0.218	0.429	0.400	0.379
Recon 121	0.425	1.01	1.07	0.931
No Scene	1.00	1.00	1.00	1.00

peak alone for Recon A, B, C, and 84 and yet be above all the clutter peaks, including those of recon 121. Recon 121 is included for clutter peaks because the peaks do derive from a non M-60 source and are therefore valid. Recon 121 did not, however, have an autocorrelation signal from the M-60 above the clutter, so its peak correlation signal was not included in this simple thresholding experiment.

Table 4 shows signal and peak clutter measurements for the 3^{rd} and 6^{th} order cases that were normalized by the scene and respective correlation plane average intensities. Note that in all cases, except Recon 121, a threshold can be easily specified to be between the smallest normalized peak autocorrelation and the largest normalized clutter signal. For example, for the 3^{rd} order case normalized to the average scene intensities, the mean of the lowest signal (exclusive of

TABLE 4 CORRELATION MEASUREMENTS NORMALIZED BY SCENE AND CORRELATION PLANE INTENSITY

	Peak Signal/ Avg Scene Intensity	Peak Clutter/ Avg Scene Intensity	Peak Signal/ Avg Scene Intensity	Peak Clutter/ Avg Scene Intensity
3rd Order MF Scene				
Recon A	2.32	0.258	1.74	0.193
Recon B	1.75	0.200	1.32	0.150
Recon C	2.24	0.207	1.95	0.181
Recon 84	1.93	0.321	1.05	0.175
Recon 121	0.282	0.565	0.112	0.224
6th Order MF Scene				
Recon A	2.52	0.194	1.86	0.143
Recon B	1.75	0.200	1.31	0.149
Recon C	1.49	0.207	1.27	0.176
Recon 84	1.47	0.459	0.806	0.252
Recon 121	0.282	0.589	0.128	0.268

Recon 121) and the highest clutter is 1.16, which has twice the magnitude of that clutter signal. Similar results are obtained for the three other cases. A similar thresholding for Recon 121 would have included a false alarm.

POINT-BY-POINT NORMALIZATION

Some preliminary experiments were performed to determine the feasibility of normalizing the intensity of the correlation plane point-by-point to the input plane intensity. It was hoped that such normalization would result in an improvement in correlation signal-to-noise ratio for Recon 121, which was previously less than one.

The 360 mm holographic transform lens was replaced with a high quality 360 mm glass lens in order to increase the intensity level at the correlation plane. The previously fabricated matched filter set produced strong autocorrelations with the standard M-60.

A Gamma-Scientific scanning microphotometer was used for both the image and 3rd order correlation plane scans. Identical horizontal scans across the M-60 were used in these experiments. The scans began inside the white road, proceeded through the tank (perpendicular to its major axis), and ended inside the large white house.

The scans across the correlation plane were made with a probe of a diameter corresponding to approximately three percent of the tank width, or approximately the width of the correlation peak. The scans across the input scene were performed by moving the 100 mm retransform lens to an on-axis position, removing the matched filter, and imaging the scene

at the focal plane of the 100 mm retransform lens. A test was performed to ensure one-to-one dimensional correspondence between the correlation plane and the imaged input scene by precisely shifting the input scene in the gate and measuring the displacements of the image and correlation plane. The test showed very precise registration.

Initially, the same size probe was used for scanning both the correlation and image planes. This probe had a diameter corresponding to three percent of the tank width. It was found that this probe was too small to be useful for terrain scans, as the scans proved to be too rapidly varying. This was due to both the fine detail in the scene and the noise problems caused by the use of coherent light. A probe having a diameter corresponding to the width of the tank was used for subsequent experiments.

Figure 22 shows the scanned (3^{rd} order) correlation plane and the scene scan for Recon 121.

Upon examination of the data it became apparent that this simple normalization scheme was effective in reducing the S/C ratio. After dividing the relative intensity of points from the correlation plane scan by the relative intensity of corresponding points from the scene scan, the signal-to-noise ratio was improved, albeit by a small amount. For example, the correlation peak at point C is the signal corresponding to the tank in Recon 121. The peak at point B has 1.68 times the intensity of the tank correlation signal, while the peaks at A and D have relative magnitudes of 0.877 and 0.523, respectively.

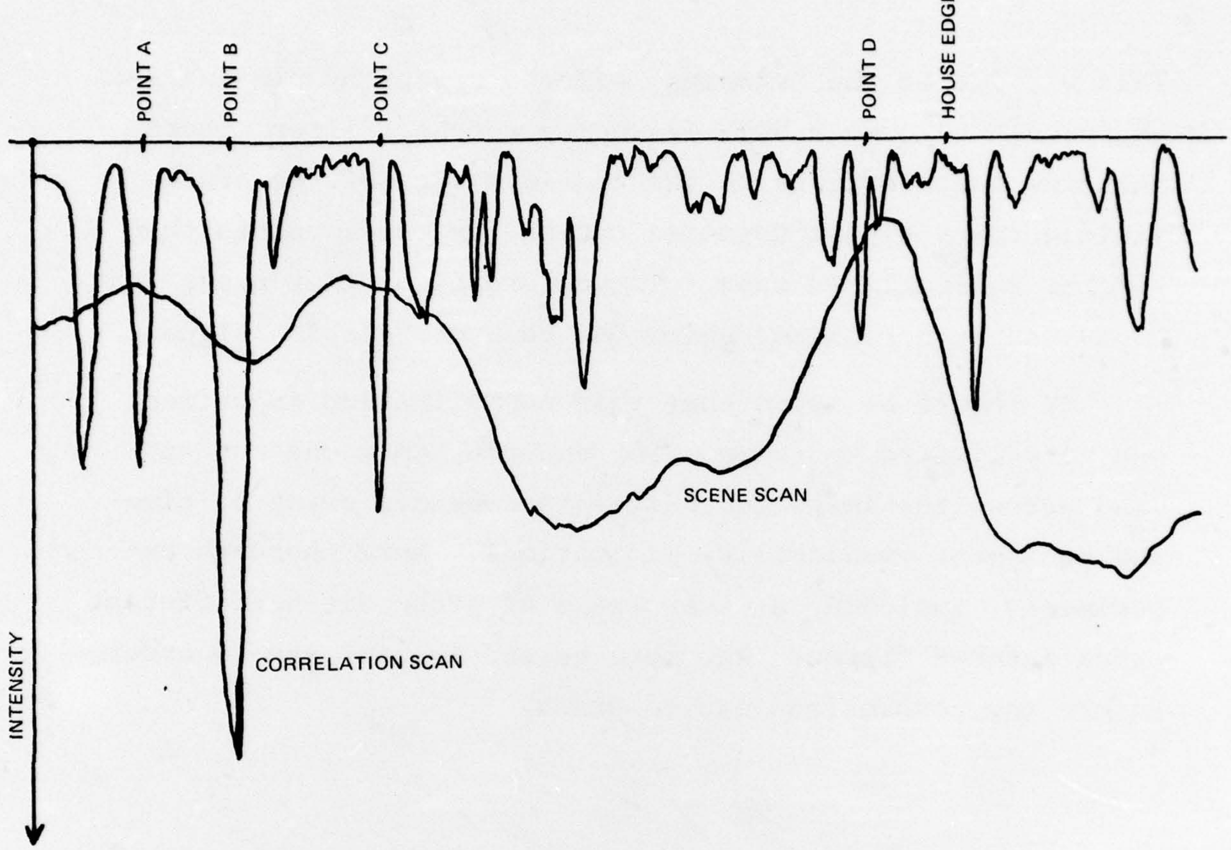

Fig. 22 Scene and Correlation Plane Scans for Recon 121

After normalization to the scene intensity scan, point B has a relative intensity of 1.24 (compared to the normalized tank signal, point C). This indicates an increase in signal-to-noise ratio for that noise peak. Points A and D have relative normalized magnitudes of 0.737 and 0.850, respectively. Note that the relative intensity of noise peak D was increased by the normalization algorithm.

Perhaps this phenomenon can be explained upon close examination of the scans near the edge of the white house. The area adjacent to this high contrast edge consists of very dark brush. The points in the correlation plane that correspond to this brush actually showed relatively high intensities.

This was due to the "ringing" effects caused by playing the sharp edge through a high frequency matched filter. Normalizing these effects to the low intensity of the brush yielded lower signal-to-noise ratios for those points than for the unnormalized case. There were also other peaks that could not be normalized below the peak correlation signal.

It should be noted that this normalization experiment was very limited in scope. For example, only one cut was used across the image and correlation planes owing to time and equipment availability limitations. More thorough experiments, including a wider range of probe sizes, different order matched filters, and more varied imagery are in order before any conclusions can be drawn.

4. CONCLUSIONS

Additional work remains to be done in the improvement of the signal-to-noise ratio for the Optical Matched Filter Image Correlator. Guidelines for matched filter optimization for different types of targets in different types of terrain have yet to be established. A method of quantitatively describing probable background terrain (possibly a spectral power density description) would undoubtedly be of value.

Adequate signal-to-noise ratios were obtained for matched filters optimized at the 3rd and 6th lobes of the M-60 spectrum in four out of the five reconnaissance cases. The matched filter optimized at the zero order, or "DC" lobe, did not seem to be effective in discriminating the target from the background. This is not entirely unexpected, as little detail information is present in the DC filter. The matched filters were able to discriminate the tank in a high contrast reconnaissance scene containing objects of size similar to the M-60 having a much larger intensity transmittance. However, the S/C ratio may in fact fall below one giving rise to some false alarms.

A normalization of the correlation plane to the total scene or correlation plane intensity seems to be of some value in determining a threshold for target presence. This type of normalization would correct for variations in average input film density or variations in laser power.

A simple application of point-by-point normalization was performed with the intent of improving the signal-to-noise ratio for the high contrast case. The results showed improvement. However the experiment was intended only to be a model

for future work and not an exhaustive treatment of point-by-point normalization. Different probe sizes should be evaluated, as well as matched filters of varying optimized order. Perhaps the correlation plane for a third order matched filter could be normalized point-by-point to the correlation plane for a DC matched filter. Again, there is much here that warrants further study.

Perhaps such a high degree of normalization is not necessary for the actual reconnaissance imagery, which is typical of one order of magnitude range in contrast (Ref. 8). Of course, film that is destined for examination by this type of system could be intentionally processed at these contrast levels. This may necessitate fabricating the matched filters from similar contrast targets. More study, however, is indicated.

In summary, the OMFIC system is capable of picking out a target in terrain, but there appear to be situations in which false targets will also be detected — a not-unusual situation for any target detection system.

5. REFERENCES

1. Vander Lugt, A., "Coherent Optical Processing," Proceedings of the IEEE, Vol. 62, p. 1300, 1974.

2. Goodman, J. W., Introduction to Fourier Optics, McGraw-Hill, Inc., pp. 77-100, 1968.

3. Goodman, J. W., "An Introduction to the Principles and Applications of Holography," Proceedings of the IEEE, Vol. 59, p. 1302, 1971.

4. Goodman, Introduction to Fourier Optics, p. 175.

5. Leib, K. G., Bondurant, R. A., and Hsiao, S., "Optical Matched Filtering Techniques for Automatic Interrogation of Aerial Reconnaissance Film," Grumman Research Department Report RE-524 (Final report on DAAG53-75-C-0199), 1976.

6. Graube, A., "Advances in Bleaching Methods for Photographically Recorded Holograms," Applied Optics, Vol. 13, p. 2942, 1974.

7. Mueller, M. R. and Carlson, F. P., "Apodization Filtering Applied to a Bandlimited Optical Fourier Transform," Applied Optics, Vol. 15, p. 690, 1976.

8. Image Interpretation Handbook, Vol. 1, U.S. Army Technical Manual, TM 30-245, pp. 2-25, 1967.